International Basic and Applied Research Journal Vol.4 No.04 (April 2018) pp. 1-8

ISSN 2576-7615

International Basic and Applied Research Journal

Visit Journal website – www.ibarj-journal.com

Research Article (Subject – Petroleum geology)

Integration of Well Logs and 3D Seismic for Prospect Evaluation in Rancho Field, Western Niger Delta

[1]Taiwo S. Olapade, [1]Oluwatoyin A. Oluwadare, [2]Solomon Mathew and [2]Muniru A. Kamilu

[1]Department of Applied Geophysics, Federal University of Technology, Akure.
[2]Department of Physical Science, Yaba College of Technology, Yaba, Lagos.

Abstract

This paper presents the result of a prospect evaluation study on Rancho oilfield in the Niger Delta. This study attempts to reduce the risk of drilling by using a multi-disciplinary approach which includes petrophysics, seismic, and volumetric methods to achieve these objectives. A combination of structural based geometric models with seismic and well data was used to constrain the interpretation. Interpretation of seismic depicts simple faulting in synthetic and antithetic growth fault. Faulted anticline and collapse-crest growth fault system were observed on the surface map. The well log types used for quantitative analysis include resistivity, density and neutron logs. The reserves were estimated using volumetric and probabilistic method and all the five reservoirs are economically viable according to the amount of hydrocarbon in place from Sand_A, to Sand_G. The Petrophysical results reveal a good porosity (0.23 – 0.27), water saturation (0.09 – 0.12) and hydrocarbon saturation (0.75 – 0.88). Reserve estimation for prospect observed in segments of the maps and Sand_A, Sand_D, Sand_E, Sand_F and Sand_G produced map based volumetric values of 29.0375mmstb, 19.90mmstb, 31.768mmstb, 16.975, and 163.586mmstb respectively.

Keywords: Seismic interpretation, Well logs, Prospect evaluation, Attribute extraction, STOIIP, Nigeria.

Introduction

Prospect evaluation is the practice of estimating a reserve through quantitative and qualitative analysis. This is done by estimating the petrophysical parameters such (Porosity, Volume of Shale, Water saturation, Hydrocarbon saturation, etc) in order to know by amount of oil in place in a reserve. This help to determine if a reserve is economically viable or not.

The integration of well log analysis and 3-D seismic interpretation, are the most efficient techniques and approaches that can be adopted to estimate the reserve of any hydrocarbon bearing field in the oil and gas industries for effective productivity in commercial quantity and profitability. Therefore, the integration of well log and seismic data would provide a high degree of reliability in mapping subsurface structural and stratigraphic plays. It will also provide insight to reservoir hydrocarbon volume which may be utilized in exploration evaluations and in well bore planning (Aizebeokhai and Olayinka, 2011). The enormous cost of exploration for this all-important resource makes it necessary for the attainment of high level of perfection in the methods adopted for its detection and quantification. Since cost effectiveness is the driving factor

in oil and gas industry, interest in reservoir evaluation is channel towards the need to quantify the reservoir with

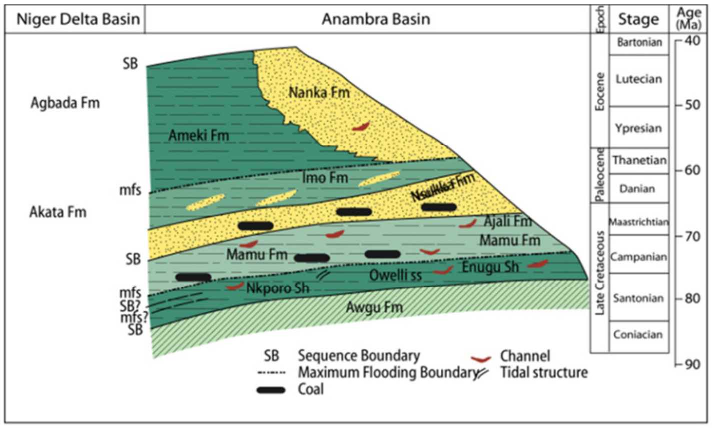


Figure 1. Stratigraphic section of the Anambra Basin. Modified from Reijers and others, 1997.

more complex geological environments and hence it is important to exploit new development with higher resolution seismic reflection methods The Niger Delta Basin to date is the most prolific and economic sedimentary Basin in Nigeria. It is an excellent petroleum province, ranked by the U.S Geological Survey World Energy Assessment as the twelfth richest in petroleum resources, with 2.2 % of the world's discovered oil and 1.4 % of the world's discovered gas (Klett et al.1997; Petroconsultants, Inc. 1996). By virtue of the size and volume of petroleum accumulation discovered in this basin, various exploration strategies have been devised to recover the enormous oil and gas deposits. These comprise onshore exploration of oil and gas as well as on continental shelf, and in deep offshore. Petroleum in the Niger Delta is produced from sandstones and unconsolidated sands predominantly in the Agbada Formation. Recognized known reservoir rocks are of Eocene to Pliocene in age, and are often stacked, ranging in thickness from less than 15 meters to 10% having greater than 45 meters' thickness (Evamy et al. 1978). Based on reservoir geometry and quality, the lateral variation in reservoirs thickness is strongly controlled by growth faults; with the reservoirs thickening towards the fault within the down-thrown block (Weber and Daukoru, 1975). The objectives of the present work are to make detailed use of available wireline log data to delineate the reservoir units in the wells, determine the geometric properties such as lithological units, gross interval, net-pay thickness, fluid contact, porosity, water

reduced level of uncertainty associated with geological models. The deposits yet undiscovered are in

saturation of the reservoir rocks with the ultimate aim of estimating reserves of hydrocarbon bearing sands in this field.

Geology of the study area

The Niger Delta is situated in the Gulf of Guinea (Figure 1) and extends throughout the Niger Delta Province as defined by Klett and others (1997). From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter (Kaplan and others, 1994).

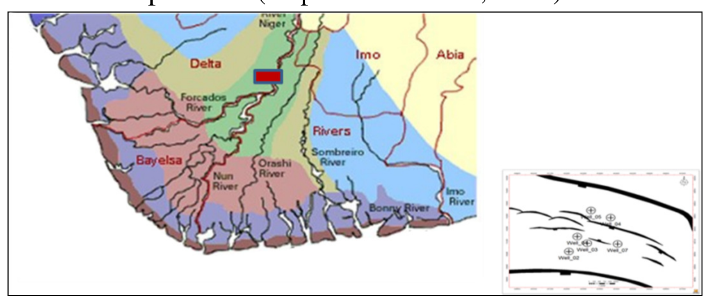


Figure 2. Basemap of Rancho Field, Niger Delta, Nigeria.

The Niger Delta Province contains only one identified petroleum system (Kulke, 1995; Ekweozor and Daukoru, 1994; this study). This system is referred to here as the Tertiary Niger Delta (Akata –Agbada) Petroleum System. The maximum extent of the petroleum system coincides with the boundaries of the province (Figure 1). The minimum extent of the system is defined by the areal extent of fields and contains known resources (cumulative production plus proved reserves) of 34.5 billion barrels of oil (BBO) and 93.8 trillion cubic feet of gas (TCFG) (14.9 billion barrels of oil equivalent, BBOE) (Petroconsultants, 1996a). Currently, most of this petroleum is in fields that are onshore or on the continental shelf in waters less than 200 meters deep (Figure 1), and occurs primarily in large, relatively simple structures. A few giant fields do occur in the delta, the largest contains just over 1.0 BBO (Petroconsultants, Inc., 1996a). Among the provinces ranked in the U.S. Geological Survey's World Energy

Assessment (Klett and others, 1997), the Niger Delta province is the twelfth richest in petroleum resources, with 2.2% of the world's discovered oil and 1.4% of the world's discovered gas (Petroconsultants, Inc. 1996a).

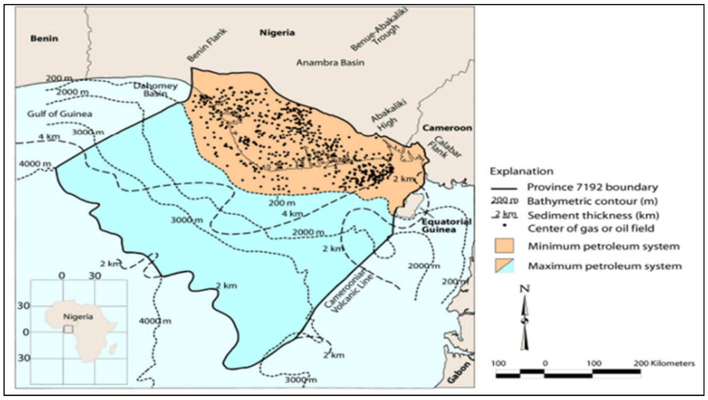


Figure 3. Map of Niger Delta showing Province outline (maximum petroleum system). Data from Petroconsultants (1996a).

The onshore portion of the Niger Delta Province is delineated by the geology of southern Nigeria and southwestern Cameroon (Figure 1). The northern boundary is the Benin flank--an east-northeast trending hinge line south of the West Africa basement massif. The northeastern boundary is defined by outcrops of the Cretaceous on the Abakaliki High and further east-south-east by the Calabar flank--a hinge line bordering the adjacent Precambrian. The offshore boundary of the province is defined by the Cameroon volcanic line to the east, the eastern boundary of the Dahomey basin (the eastern-most West African transform-fault passive margin) to the west, and the two-kilometer sediment thickness contour or the 4000-meter bathymetric contour in areas where sediment thickness is greater than two kilometers to the south and southwest. The province covers 300,000 km^2 and includes the geologic extent of the Tertiary Niger Delta (Akata-Agbada) Petroleum System.

Methodology

Identification of Hydrocarbon-Bearing Reservoirs

Hydrocarbon bearing reservoirs in the four wells were identified, digitized and named as explained below:

1. Porous and permeable beds are identified by the nature of the signatures of SP and Resistivity logs.
2. The boundaries of these reservoirs are established with the GR log.
3. A very high resistivity value within the established reservoir thus finally defines a hydrocarbon bearing reservoir.
4. The reservoirs are then named. The log values are sampled at a predetermined interval within the reservoir.

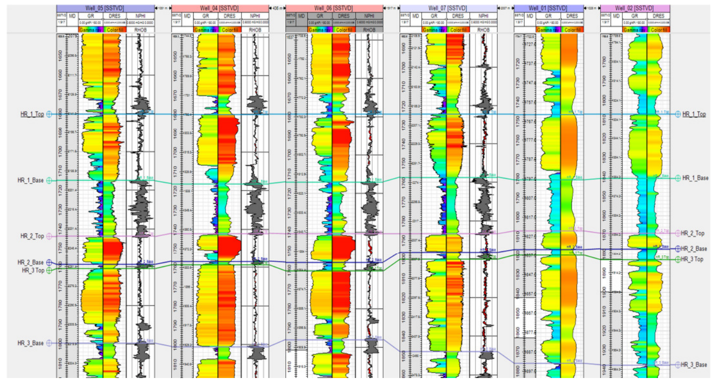


Figure 4. Qualitative interpretation (Well correlation) of Well_01, to Well_07.

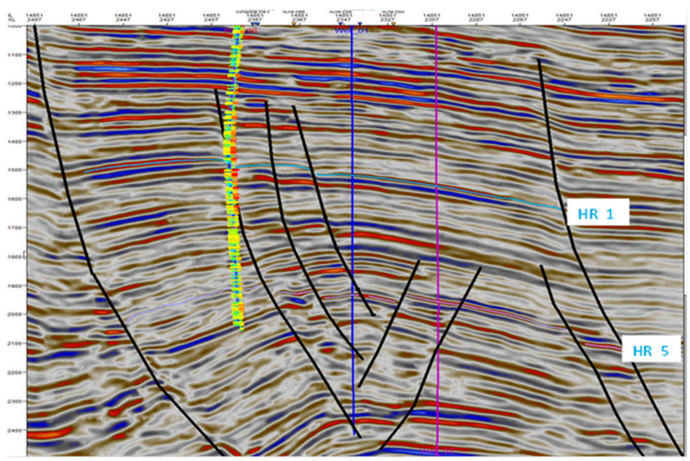


Figure 5. Seismic section showing both synthetic and antithetic fault.

Determination of gross and net sand reservoir thickness

The gross reservoir thickness interval is the interval covering both sand and shale only within a reservoir. The net sand thickness is the interval covering sand only within the reservoir. It is also known as the net productive sand.

Correlation of the reservoirs

The correlation panels of the four wells in Rancho field are presented in chapter four. The correlation direction is from Northwest to Southeast. The spatial locations of the wells are taken into consideration in setting-up the correlation and its direction.

The Gamma ray (GR) log and Deep Induction (ILD) or Deep Resistivity (DRES) log were employed for lithological correlation across the four wells in Figure 4. The top and base of seven reservoirs were correlated across four wells. These reservoirs are Sand_A, Sand_B, Sand_C, Sand_D, Sand_E, Sand_F, Sand_G.

Table 1 and 2 shows the Tops, base, fluid types and contact depth in Subsea True Vertical Depth (SSTVD) for different sand pack.

Table 1. Petrophysical parameter estimation for horizon 1.

RANCHO 1					
PARAMETERS	Sand A	Sand D	Sand E	Sand F	Sand G
Top (m)	2977	3280	3380	3440	3495
Base (m)	3016	3298	3412	3455	3570
Gross Thickness	39	18	32	15	75
Net Thickness	36	17.3	26	12	73.5
NTG	0.90	0.95	0.75	0.70	0.93
Porosity (%)	24	27	23	24	23
Sw (%)	10	18	14	11	12
Sh (%)	88	86	75	76	88

Table 2. Petrophysical parameter estimation for horizon 5.

RANCHO 5					
PARAMETERS	Sand A	Sand D	Sand E	Sand F	Sand G
Top (m)	2977	3280	3380	3440	3495
Base (m)	3016	3298	3412	3455	3570
Gross Thickness	39	18	32	15	75
Net Thickness	36	17.3	26	12	73.5
NTG	0.90	0.95	0.75	0.70	0.93
Porosity (%)	24	27	23	24	23
Sw (%)	10	18	14	11	12
Sh (%)	88	86	75	76	93

Computation of petrophysical parameters

True Formation Resistivity (R_t)

This is the true resistivity of a formation. It is measured by a deep reading resistivity log such as Deep Induction Log (ILD) or Deep Laterolog (LLD).

The ILD log signature across each reservoir formation in each well is examined and sampled to obtain its average value in each of the hydrocarbon reservoir. This gives the true resistivity R_t of each reservoir.

Gamma Ray Index (I_{GR})

Determining the gamma ray index (I_{GR}) is the first step needed to evaluate the volume of shale V_{sh} in porous reservoirs. They are applied in the analysis of shaly sands.

The gamma ray index I_{GR} is given by:

$$I_{GR} = \frac{GRlog - GRmin}{GRmax - GRmin}$$

Volume of Shale (V_{sh})

The volume of shale V_{sh} is obtained, either from appropriate charts, or mathematically from the following relationships using the I_{GR}. The mathematical relationships are;

Dresser Atlas (1979) formulae

$V_{sh} = 0.083\ [2^{(3.7 \times I_{GR})} - 1.0]$ (Tertiary and unconsolidated rocks)

Porosity (Ø)

Based on the available data, density derived porosity $Ø_{DEN}$ is computed and corrected for shale effect using the Dresser Atlas, (1979) equation.

The density derived porosity $Ø_{DEN}$ is given by;

$$Ø_{DEN} = \left(\frac{\rho ma - \rho b}{\rho ma - \rho f}\right)$$

Fault mapping

Major synthetic and antithetic normal fault patterns and types were mapped across seismic data (Figure 5). These fault were mapped along consistent vertical discontinuities in amplitude reflections observed along seismic section. Fault polygons were also generated around area of map discontinuity.

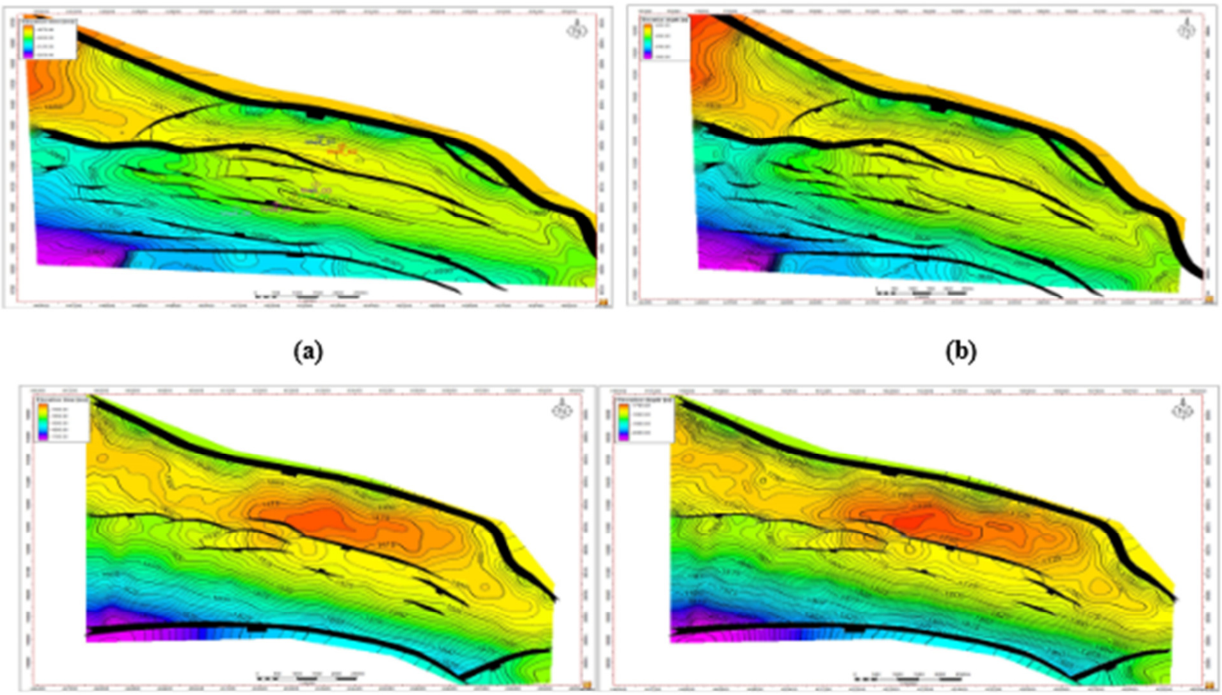
Both synthetic and antithetic faults (fault dipping in the same direction with the major bounding fault those that are dipping in opposite direction to the major bounding fault) were mapped on the seismic section.

Result and Discussion

Figure 6 below shows the time and depth structure map for horizon_1 at the depth of (-1465 to -1675) for the time map, and (-1650 to -2025) for the depth map including the interpreted fault and anticlinal trap. It is a fault assisted closure which shows the prospect area for hydrocarbon accumulation.

Also in the figure 6 below shows the regional, synthetic and antithetic fault dipping in north-east and south-west (NE-SW) direction.

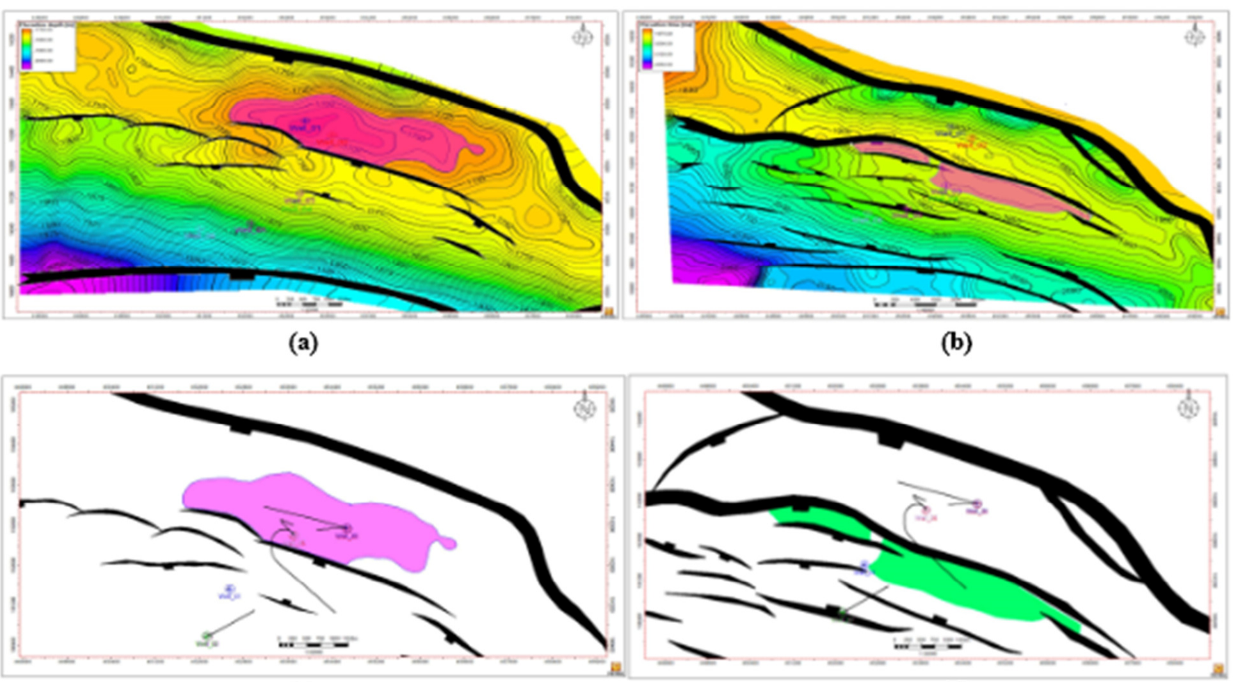
Also in Figure 6 below shows the time and depth structure map for horizon 5 at the depth of (-1900 to -2250) for the time map and (-2400 to -3000) for the depth map including the interpreted fault and anticlinal trap. It is a fault assisted closure which shows the prospect area for hydrocarbon accumulation.



(a) (b)

(c) (d)

Figure 6. showing (a) Time structure map of horizon 1 (b) Depth structure map of horizon 1 (c) Time structure map of horizon 5 (d) Depth structure map of horizon 5.



(a) (b)

(c) (d)

Figure 7. Showing (a) Prospect area for horizon 1 (b) Prospect area for horizon 5 (c) Prospect map for horizon 1 (d) Prospect area for horizon 5.

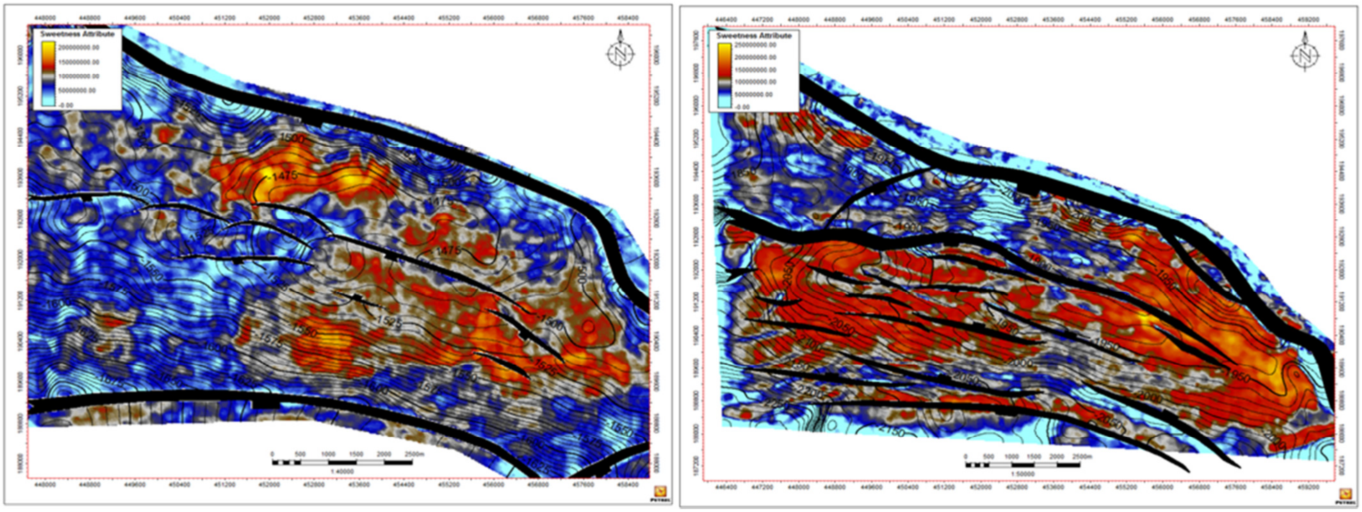


Figure 8. Attribute extraction (Sweetness) of horizon 1 and 5.

Also in the figure 6 below shows the regional, synthetic and antithetic fault dipping in north-east and south-west direction.

Well_01, well_02, well_03 and well_05 all superimposed on prospect area of time surface map of horizon 5.

On figure 7, the prospect area (fault-assisted closure) with pink coloured superimposed with well_01, well_02, well_03 and well_05. This is a drillable prospect and it was economically viable after the estimation.

Figure 9 shows the prospect map for horizon 1 and 5. On figure 9, well_01, well_02, well_05, well_06 superimposed on the prospect map. Also on figure 9, well_01, well_03, well_05, well_06 superimposed on the prospect map.

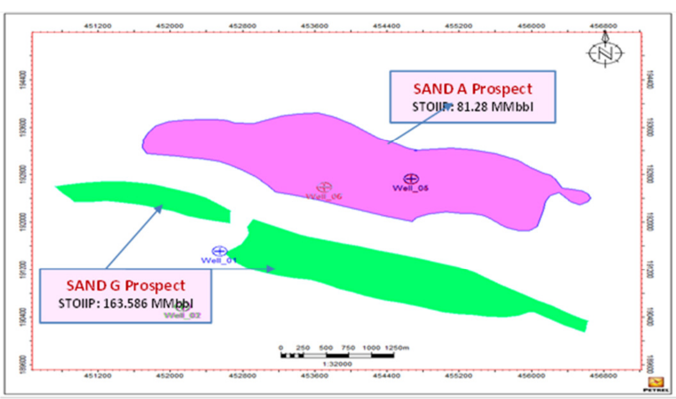


Figure 9. Prospect Map of Rancho Field, Niger Delta.

Figure 8 shows the attribute extracted on both the horizon 1 and 5. The sweetness attribute was used in order to have better information on the surface map generated and which eventually shows sand development on both horizons.

Table 3 shows the Stock Tank Oil Initially in Place (STOIIP) for horizon 1 and 5. I decided to calculate STOIIP for only this two horizons and based on the calculation, horizon 1 has 81.28bmmbbl (million barrel) of oil while horizon 5 has 11.07mmbbl of oil which are both highly productive and economically viable.

Table 3. Stock Tank Oil Initially In Place (STOIIP).

VOLUMETRICS												
FIELD	SAND	CONTACT	Fluid	AREA	THICKNESS	GRV	NTG	PHI	Shc	Conversion factor	FVF (Bo)	STOIIP
		m SSTVD		km^2	m	mmcum	Frac	Frac	Frac			mmbbl
RANCHO FIELD	SAND A	1520	Oil	4.763	37	176.5744	0.85	0.24	0.88	6.2897	1.3	81.28742552
	SAND D	1430	Oil	1.038	18	18.648	0.95	0.27	0.86	6.2897	1.3	19.90236379
	SAND E	1500	Oil	1.586	32	50.752	0.75	0.23	0.75	6.2897	1.3	31.76801676
	SAND F	1560	Oil	1.832	15	27.48	0.70	0.24	0.76	6.2897	1.3	16.97564097
	SAND G	1760	Oil	2.395	75	179.625	0.93	0.23	0.88	6.2897	1.3	163.5862576

Conclusions

In Rancho Field, five sands at the producing sequence of about 2980 – 3570ft SSTVD were identified and five hydrocarbon bearing sand unit lying within this depth namely, Sand_1, Sand_5.

Interpretation of seismic depict simple faulting were obtained in synthetic and antithetic growth fault. The

structure map generated shows that the northern area is characterized by anticlinal structures which is fault assisted closure bounded by one major bounding (Regional) fault. Faulted anticline and collapse-crest growth fault system.

The reserve was estimated using volumetric and probabilistic method and it was affirming that the prospect areas are economically viable for all the five reservoirs.

All the five reservoirs are economically viable according to the amount of hydrocarbon in place from Sand_1, Sand_5.

Recommendation

Based on the results obtained for the study and challenges encountered during course of this work it is therefore recommended that:

1. It is highly recommended that all the five wells are productive and economically viable based on the result of the research. Therefore, production should be made on the field.

2. More research work should be done on the field such as seismic structure analysis. This will shed more light on the geological structures that may be responsible for hydrocarbon entrapment;

3. Well log data of high accuracy should be available to the students for petrophysical analysis;

4. More well data should be made available, and that wells area spread across the particular field of study so as to achieve more accurate estimation of parameters in the field;

5. It is strongly recommended that the exploratory wells are drilled in the western part of the map and completion of the workflow and it was affirming that the reservoirs are economically viable for production.

Reference

Aizebeokhai, A. P. and Olayinka, I. (2011). Structural and Stratigraphic Mapping of Emi Field, Offshore Niger Delta. *Journal of Geology and Mining Research*, 3, 2, 25-38.

Avbovbo, A.A. (1978). Tertiary lithostratigraphy of Niger Delta. *American Association of Petroleum Geologists Bulletin*, 62, 295 - 300.

Doust, H. (1990). *Petroleum geology of the Niger Delta*: Geological Society, London, Special Publications, pp. 365.

Doust, H., and Omatsola, E. (1990). Niger Delta, In, Edwards, J. D., and Santogrossi, P.A., Eds., *Divergent/Passive Margin Basins,* AAPG Memoir 48, Tulsa, pp.239-248.

Ekweozor, C.M., and Daukoru, E.M. (1994). Northern delta depobelt portion of the Akata-Agbada(!) petroleum system, Niger Delta, Nigeria, in, Magoon, L.B., and Dow, W.G., eds., *The Petroleum System—From Source to Trap,* AAPG Memoir 60, pp. 599-614.

Evamy, D.D., J. Haremboure, P. Kamerling, W.A Knaap, F.A. Molloy, and P.H. Rowlands. (1978). Hydrocarbon Habitat of Tertiary Niger Delta. *AAPG Bulletin*, 62, 1-39.

Klett, T. R., Ahlbrandt, T. S., Schmoker, J. W. & Dolton, J. L. (1997). Ranking of the world's oil and gas provinces by known petroleum volumes: U.S. Geological Survey Open-file Report-97-463, CD-ROM.

Kulke, H. (1995). in, Kulke, H., ed., Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica, Berlin, Gebrüder Borntraeger, p. 143-172.

Petroconsultants (1996). Petroleum exploration and production database. Houston, Texas, Petroconsultants, Inc.

Tuttle, M.L.W., Charpentier, R.R., and Brownfield, M.E. (1990). Tertiary Niger Delta (Akata-Agbada) Petroleum System (No. 701901), *Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa*, *in* USGS, ed., The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa: Denver, Colorado, U.S. Department of The Interior S. Geological Survey.

Weber, K.J. and Daukoru, E. (1975). Petroleum Geology of the Niger Delta. *9th World Petroleum Congress Proceedings*. 2, pp. 209-221.

Cite this article: Olapade T. S., Oluwadare O. A, Mathew S. and Kamilu M. A. 2018. Integration of Well Logs and 3D Seismic for Prospect Evaluation in Rancho Field, Western Niger Delta. International Basic and Applied Research Journal, volume 4, issue no. 4, pp. 1-8.